"rectangular skein"—a vertical skein in which the permeate collection means has a configuration of a rectangular parallelpiped.

"skein"—used for brevity to refer to either a cylindrical skein or a vertical skein, or both, having plural arrays potted in opposed headers, the fibers having a critically defined length relative to the vertical distance between headers of the skein. The defined length limits the side-to-side movement of the fibers in the substrate in which they are deployed, except near the headers where there is negligible movement.

"skein fibers"—fibers which make up the cylindrical skein

"vertical skein"—an integrated combination of structural elements including (i) a multiplicity of vertical fibers of substantially equal length; (ii) a pair of headers in each of which are potted the opposed terminal portions of the fibers so as to leave their ends open; and, (iii) permeate collection means held peripherally in fluid-tight engagement with each header so as to collect permeate from the ends of the fibers.

"substrate"—multicomponent liquid feed.

"particulate matter"—micron-sized (from 1 to about 44 μcm) and sub-micron sized (from about 0.1 μm to 1 μm) filtrable matter which includes not only particulate inorganic matter, but also dead and live biologically active microorganisms, colloidal dispersions, solutions of large organic molecules such as fulvic acid and humic acid, and oil emulsions.

"restrictedly swayable"—the extent to which fibers may sway in a zone of confinement, which extent is determined by the free length of the fibers relative to the fixedly spaced-apart headers, and the turbulence of the substrate.

"stack of arrays"—plural rows of arrays, which are densely packed to form, after they are potted, a skein.

"substantially concentrically"—describes a configuration in which in which individual fibers are either vertical and spaced apart along the circumference of a circle drawn about the central vertical axis, or, spirally disposed, successive layers of the fibers typically being closely spaced-apart in the x-y plane, not only radially outwards from the central axis, but also along the spiral in that plane so that they appear to be concentrically distributed at successively increasing radial distances from the central axis.

"transmembrane pressure differential"—pressure difference across a membrane wall, resulting from the process conditions under which the membrane is operating.

"unsupported"—not supported except for spacer means to space the headers.

"vacuum pump"—capable of generating a suction of at least 75 cm of Hg.

"zone of confinement" (or "bubble zone")—a zone through which bubbles rise along the outer surfaces of the fibers. The bubble zone, in turn, is determined by one or more columns of vertically rising gas bubbles generated near the base of a skein.

We claim:

1. In a gas-scrubbed assembly comprising, a microfiltration membrane device in combination with a gas-distribution means to minimize build-up of particulate deposits on the surfaces of hollow fiber membranes ("fibers") in said device, and to recover permeate from a multicomponent liquid substrate while leaving particulate matter therein, said membrane device comprising,

a multiplicity of fibers, unconfined in a shell of a module, said fibers being swayable in said substrate, said fibers being subject to a transmembrane pressure differential in the range from about 0.7 kPa (0.1 psi) to about 345 kPa (50 psi);

a first and second header disposed in transversely spaced-apart relationship within said substrate, each header being formed with a potting resin cured in a resin-confining means;

said first header and second header having opposed terminal end portions of each fiber sealingly secured therein, all open ends of said fibers extending from a permeate-discharging face of at least one header;

permeate collection means to collect said permeate through at least one of said headers sealingly connected in open fluid communication with permeate-discharging faces of said headers;

means for withdrawing said permeate; and,

said gas-distribution means is located within a zone beneath said skein, said gas-distribution means having through-passages therein adapted to have sufficient gas flowed therethrough to generate enough bubbles flowing in a column of rising bubbles between and around said skein fibers, to keep surfaces of said fibers awash in bubbles;

said fibers, said headers and said permeate collection means together forming a vertical cylindrical skein wherein said fibers are essentially vertically disposed; said first header being upper and disposed in vertically spaced-apart relationship above said second header with opposed faces of said headers at a fixed distance, said fibers being substantially concentrically disposed relative to the vertical axis between said headers;

each of said fibers having substantially the same length, said length being from at least 0.1% greater, to less than 5% greater than said fixed distance so as to permit restricted displacement of an intermediate portion of each fiber, independently of the movement of another fiber;

the improvement comprising,

each said header having said fibers spaced apart by a flexible support means having a thickness corresponding to a desired lateral spacing between adjacent fibers, said support means extending over only each terminal portion of said fibers near their ends, so as to maintain said ends in closely-spaced apart relationship,

said gas distribution means being disposed between said fibers and having through-passages adapted to discharge said bubbles which rise vertically substantially parallel to, and in contact with said fibers, movement of which is restricted within said column;

whereby said permeate is essentially continuously withdrawn.

2. The gas-scrubbed assembly of claim 1 wherein,

said restricted displacement is in the lateral or horizontal direction,

said headers are non-removably formed within said resin-confining means, and, said gas-distribution means includes an aerator means disposed adjacent to said lower header's upper face discharging said gas in an amount in the range from 0.47–14 cm^3/sec per fiber (0.001 scfm/fiber to about 0.03 scfm/fiber), said aerator means generating bubbles having an average diameter in the range from about 0.1 mm to about 25 mm, said bubbles maintain outer surfaces of said fibers essentially free from build-up of deposits of said particulate matter.

3. The gas-scrubbed assembly of claim 2 wherein,
said gas-distribution means includes a vertical member centrally axially disposed within said skein and through at least one said header;
said length is from 1% to less than 5% greater than said fixed distance,
said fibers together have a surface area >1 m^2, each fiber has a length >0.5 meter,
said fibers together have a surface area in the range from 10 to 10^3 m^2,
said headers are vertically adjustable to provide said fixed distance, and,
said bubbles are in the size range from 1 mm to 25 mm measured in relatively close proximity, in the range from 1 cm to about 50 cm, to said through-passages.

4. The gas-scrubbed assembly of claim 2 wherein,
each header includes both, a fiber-setting form to hold and set said fibers in a chosen pattern, and spacer means to maintain desired fiber-to-fiber spacing within said skein, said both being integral with said header;
said fibers are potted within said synthetic resinous material to a depth in the range from about 1 cm to about 5 cm and protrude through a permeate-discharging face of each said header in a range from about 0.1 mm to about 1 cm.

5. The gas-scrubbed assembly of claim 3 wherein,
said permeate collection means includes a vertical member coaxially disposed within said gas distribution means' vertical member,
said substrate is maintained at a pressure in the range from about 1–10 atm,
said transmembrane pressure differential is in the range from 3.5 kPa (0.5 psi) to about 175 kPa (25 psi),
opposed terminal end portions of said fibers are in open communication with each other through each said header;
said fibers are in the range from 0.5 m to 5 m long, and,
said terminal end portions of said fibers are potted within said mass of resin to a depth in the range from about 1 cm to about 5 cm.

6. The gas-scrubbed assembly of claim 5 wherein said particulate matter comprises biologically active microorganisms growing in said substrate.

7. The gas-scrubbed assembly of claim 5 wherein said particulate matter comprises finely divided inorganic particles.

8. The gas-scrubbed assembly of claim 1 wherein,
each said fiber is formed from a material selected from the group consisting of natural and synthetic polymers, has an outside diameter in the range from about 20 μm to about 3 mm, a wall thickness in the range from about 5 μm to about 2 mm, and, a pore size in the range from 1000 Å to 10000 Å, each said header is a cylindrical disc having substantially the same dimensions, and, said gas is a molecular oxygen-containing gas.

9. In a microfiltration membrane device, for withdrawing permeate essentially continuously from a multicomponent liquid substrate, said membrane device including:
a multiplicity of hollow fiber membranes, or fibers, unconfined in a shell of a module, said fibers being swayable in said substrate, said fibers being subject to a transmembrane pressure differential in the range from about 0.7 kPa (0.1 psi) to about 345 kPa (50 psi);
a first header and a second header disposed in transversely spaced-apart relationship with said second header within said substrate;
said first header having a terminal end portion of each fiber secured therein, and said second header having an opposed terminal end portion of each fiber secured therein, all said fibers extending from a permeate-discharging face of at least one said header;
said fibers being sealingly secured with open ends of the fibers secured in fluid-tight relationship with each other in at least one of said headers;
permeate collection means to collect said permeate through at least one of said headers sealingly connected in open fluid communication with permeate-discharging faces of said headers;
and, means for withdrawing said permeate;
said fibers, said headers and said permeate collection means together forming a vertical cylindrical skein wherein said fibers are essentially vertically disposed; said first header being upper and disposed in vertically spaced-apart relationship above said second header, with opposed faces at a fixed distance;
each of said fibers having substantially the same length, said length being from 0.1% to less than 5% greater than said fixed distance so as to permit restricted displacement of an intermediate portion of each fiber, independently of the movement of another fiber;
the improvement comprising,
each said header having said fibers spaced apart by a flexible support means having a thickness corresponding to a desired lateral spacing between adjacent fibers, said support means extending over only each terminal portion of said fibers near their ends so as to maintain said ends in closely-spaced apart relationship.

10. The membrane device of claim 9 wherein,
each said header is a mass of synthetic resinous material in which said terminal end portions are potted and said fibers are formed from natural or synthetic polymers;
each said fiber has an outside diameter in the range from about 20 μm to about 3 mm, a wall thickness in the range from about 5 μm to about 2 mm, pore size in the range from 1,000 Å to 10,000 Å; and, said displacement is in the lateral or horizontal direction.

11. The membrane device of claim 10 wherein,
said permeate collection means includes a vertical member axially disposed through
said headers and within said skein,
said substrate is maintained at a pressure in the range from about 1–10 atm, said fibers extend as a skein upwardly from a fiber-supporting face of each of said headers, each header has substantially the same dimensions, said fibers extend downwardly through the permeate-discharging face of said headers, and said permeate is discharged upwardly relative to said upper header.

12. The membrane device of claim 11 wherein,
said fibers together have a surface area >1 m^2, each fiber has a length >0.5 meter, said fibers together have a surface area in the range from 10 to 103 m^2 and, said terminal end portions of said fibers protrude through a permeate-discharging face of each said header in a range from about 0.1 mm to about 1 cm.

13. In a process for maintaining the outer surfaces of hollow fiber membranes essentially free from a build-up of deposits of particulate material while separating a permeate from a multicomponent liquid substrate in a reservoir, said process comprising,
submerging skein fibers in an essentially vertical, cylindrical configuration within said substrate, said fibers

being unconfined in a modular shell, and securely held in vertically opposed, upper and lower headers spaced-apart at a fixed distance, said fibers having substantially the same length and from at least 0.1% greater, to about 5% greater than said fixed distance, a transmembrane pressure differential in the range from about 0.7 kPa (0.1 psi) to about 345 kPa (50 psi), and length sufficiently greater than the direct distance between opposed faces of said first and second headers, so as to present said skein in a swayable configuration above a horizontal plane through the horizontal center-line of said lower header;

mounting said headers in fluid-tight open communication with collection means to collect said permeate;

flowing a fiber-cleaning gas through a gas-distribution means proximately disposed relative to said skein, within a zone beneath said skein, and contacting surfaces of said fibers with sufficient physical impact of bubbles of said gas to maintain essentially the entire length of each fibers in said skein awash with bubbles and essentially free from said build-up;

maintaining an essentially constant flux through said fibers substantially the same as an equilibrium flux initially obtained after commencing operation of said process;

collecting said permeate in said collection means; and, withdrawing said permeate,

the improvement comprising,

introducing said cleansing gas between said fibers within said skein to generate a column of said bubbles alongside and in contact with outer surfaces

of said fibers; said fibers spaced apart by a flexible support means having a thickness corresponding to a desired lateral spacing between adjacent fibers, said support means extending over only each terminal portion of said fibers near their ends, so as to maintain said ends in closely apart relationship;

restricting movement of said fibers to said vertical zone defined by lateral movement of outer fibers in said skein;

vertically gas-scrubbing said fibers outside surfaces with bubbles which flow upward in contact with said surfaces;

maintaining said surfaces substantially free from said deposits of particulate matter during a period when flux through said fibers has attained equilibrium; and

simultaneously, essentially continuously, withdrawing said permeate.

14. The process of claim 13 wherein,

each said hollow fiber has an outside diameter in the range from about 20 μm to about 3 mm, and a wall thickness in the range from about 5 μm to about 1 mm;

said particulate matter is selected from the group consisting of microorganisms and finely divided inorganic particles; and,

said gas-distribution means discharges gas in an amount in the range from 0.47–14 cm^3/sec per fiber (0.001 scfm/fiber to about 0.03 scfm/fiber) and generates bubbles having an average diameter in the range from about 1 mm to about 25 mm.

15. A system for treating a multicomponent liquid substrate while leaving particulate matter therein, comprising,

(a) a non-pressurized reservoir other than a shell of a module for containing the substrate;

(b) a cylindrical skein of hollow fiber filtering membranes immersed in said substrate and having said membranes disposed generally vertically between upper and lower headers such that (i) outsides of ends of said membranes are sealingly secured to the headers in a closely spaced apart relationship, (ii) lumens of said fibers being in fluid communication with at least one permeate collection means, and, (iii) said fibers having a length in the range from 0.1% to 5% greater than the distance between headers;

(c) a pump in fluid communication with said lumens of said membranes through at least one permeate collection means, said pump operable to apply a suction to the lumens of the membranes to draw a component of the substrate as permeate through said membranes while leaving particulate matter in said substrate; and,

(d) aeration means providing a column of rising bubbles near said outsides of said membranes' lower ends.